# High-Resolution Mesoscale Atmospheric Model Prediction and Validation


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## LONG-TERM GOAL

The long-term goals of this project are: (i) explore and test new techniques that can improve the application of the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS™)[1] high-resolution nested grids, (ii) to develop new mesoscale model verification techniques to objectively validate the model forecast, (iii) to perform model validation, and (iv) use the validation results as guidance to improve COAMPS high-resolution grid forecasts.

## OBJECTIVES

Compare validation results on COAMPS coarse and fine grids. Investigate methods and type of observations that can be used for validation on high-resolution mesoscale model forecasts. Improve flexibility of COAMPS fine grid initialization and displacements.

## APPROACH

Validation of the model Quantitative Precipitation forecast (QPF), wind forecast, and other model statistics are important to gauge the performance of COAMPS. Our approach is to examine the COAMPS cold and warm season QPF statistics to establish baseline statistics for future comparison. Case studies are performed to understand the causes of model precipitation bias using the NCEP rain gauge analysis over the CONUS region. Rule-based algorithms are developed to test the composite verification method for partially observed high wind events near the ocean surface. The composite technique is a relative simple method compared to more complex pattern shifting. It relaxes the observation requirements on any one event and allows a partially observed event to be smoothly incorporated into a coherent, statistically meaningful comparison.

To improve the application of COAMPS high resolution nested grids, our approach is to incorporate a delayed nest option that uses the moving nest algorithm. The delayed nest can reduce the overall wall time needed to generate the forecast and allow even finer grids to track features of interest.

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14. ABSTRACT
**The long-term goals of this project are: (i) explore and test new techniques that can improve the application of the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPSTM)1 high-resolution nested grids, (ii) to develop new mesoscale model verification techniques to objectively validate the model forecast, (iii) to perform model validation, and (iv) use the validation results as guidance to improve COAMPS high-resolution grid forecasts.**

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## WORK COMPLETED

1. Validated the COAMPS 2002 cold season quantitative precipitation forecasts.-Used the event verification technique to obtain the observed and the model precipitation distribution climatology in addition to the grid averaged equitable threat and bias scores.

   -Performed one-week case studies to investigate the causes for the model precipitation deficiency.

2. Completed the wind event-based verification study.

   -Developed the algorithm for high wind event composites near the ocean surface.

   -Validated COAMPS wind forecast over the Mediterranean and eastern Pacific Ocean.

3. Developed the delayed nested grid ability.

## RESULTS

*COAMPS QPF Validation:* The COAMPS precipitation statistics for the 2001 cold season were computed using the 27 km operation CONUS forecasts with eight different thresholds of rain rate. The time period is from mid November 2001 through 30 April 2002. Due to various data collecting problems, 111 days statistics are actually used for the average.

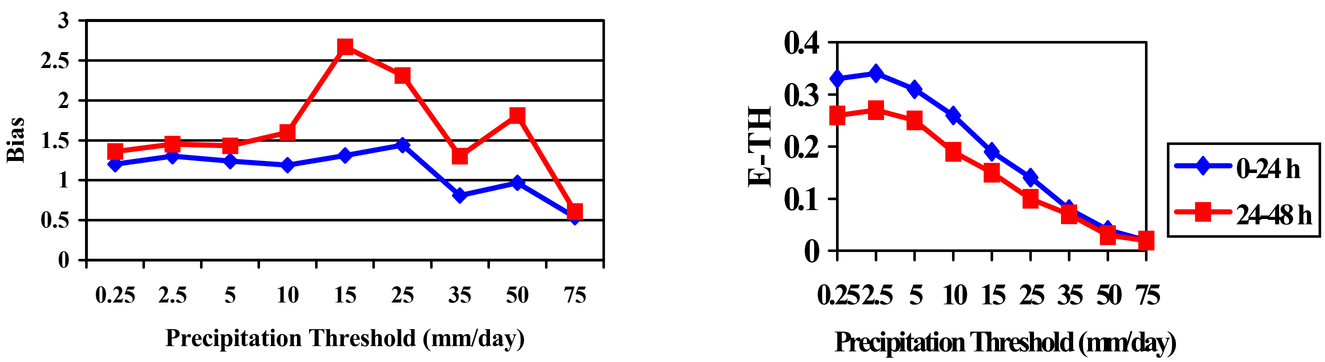


***Figure 1. COAMPS bias (left) and equitable threat scores (right) for precipitation thresholds of 0.25 to 75 mm/day. The blue line with diamonds represents the 0-24 hour forecast and the red line with squares represents the 24-48 hour forecast.***

Note that in Fig.1 (left), the comparison of the averaged COAMPS rain area coverage (represented by the bias score) with the observations indicates: for rain amounts < 35 mm/day, the area was over-predicted, i.e., bias>1; for rain amounts >35mm/day the rain area was under-predicted. Comparison of the 0-24 and 24-48 hour forecasts bias scores shows the model has a positive precipitation bias with increasing forecast time. The COAMPS relative humidity field also showed the same bias trend indicating the precipitation problem was related to an increase in the modeled moisture with time. Since the bias scores are close to one for a rain rate <50 mm/day, the low threat score in Fig. 1 (right) seems to indicate the COAMPS forecasts do not produce enough "exact" rain coverage suggesting a possible phase shift problem. For a rain rate > 75 mm/day, both the bias and threat scores are low suggesting the model does not forecast enough heavy precipitation. Further examination shows that less than 20% of the total model forecast rain is convective for the rain rate > 35 mm/day.

Additional model runs were performed for a one-week period (1200 UTC 25 January to 1 February 2002) to investigate the model precipitation bias. Two 9km domains are added to the operational CONUS domain. The precipitation for the 9 km domains is explicitly resolved by the model microphysics scheme (e.g. the convective scheme is not turned on). A bench run using the current version of microphysics and a sensitivity run using the improved microphysics (Schmidt 2001) are examined. The one-week case study shows that increasing resolution improved the model QPF. When using the new microphysics, even more QPF improvements are obtained. Similar to the 27 km cold season QPF results, the case studies indicate possible precipitation deficiency from the COAMPS convective scheme.

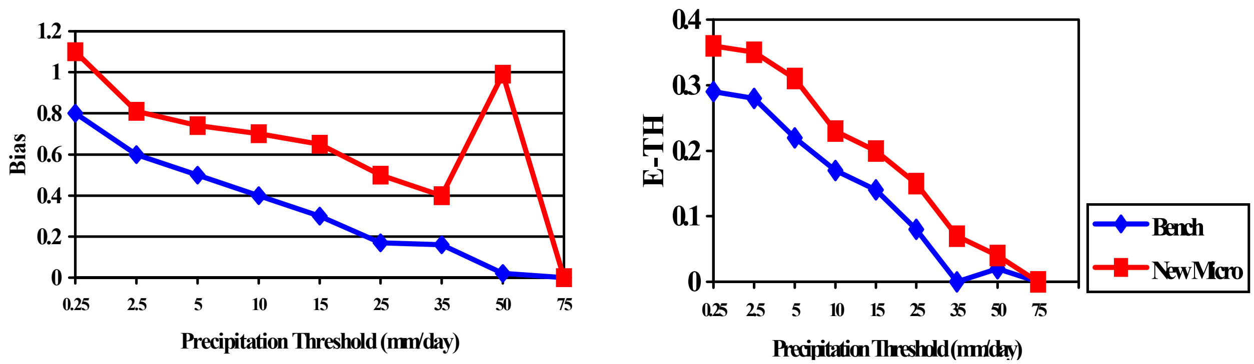


***Figure 2. Comparison of COAMPS equitable threat scores between the standard (bench) and the improved microphysics (moist) runs (a) at 27 km resolution over the CONUS region.***

*Wind Event Composite Verification*: A rules-based algorithm was developed to define unique, contiguous high wind events in each forecast. A sub-domain was defined on the 27 km model grid in which the algorithm searched for high wind. Once an event was identified, all surrounding data were transferred to a 31X31 point relative grid with the same grid spacing as the model. The center of the forecast event as defined by its "center of mass" was positioned at the center of the relative grid. At that point, all available observational data were also positioned on the relative grid. Model data were then templated by the available observations, such that all forecasts outside of the SSM/I swath were cut from the set (Fig. 3). Transferring the events to the relative grid effectively synchronizes them about a common central point. With the composite method, information regarding where the model predicts events with respect to when and where the events occur can then be obtained. The rate of under-versus-over prediction can be derived as well as any consistent phase errors.

The composite technique is applied to validate the COAMPS wind forecast at the Mediterranean and eastern Pacific. The results showed direct correlations between the model and observed speed distributions (Fig.4) are quite high through the forecast period for the Mistral. The bias and RMS errors, though steadily increasing, stay relatively low through 66 hours, indicating that the distributions are relatively well synchronized. In general, Mistral winds were almost always observed when the model predicted them, and were almost always correctly forecast when they were observed. However, the core winds in the model were shifted to the southwest by about 50 km. Also, winds at the eastern and western edges of the Mistral were not as well forecast, indicating that the model does not necessarily predict the exact shape of the Mistral.

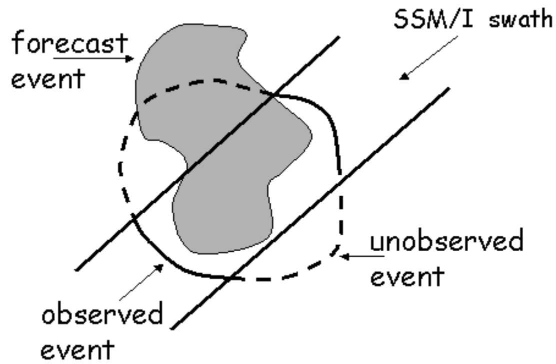


***Figure 3. Schematic depicting the data collection strategy for the event composites.***

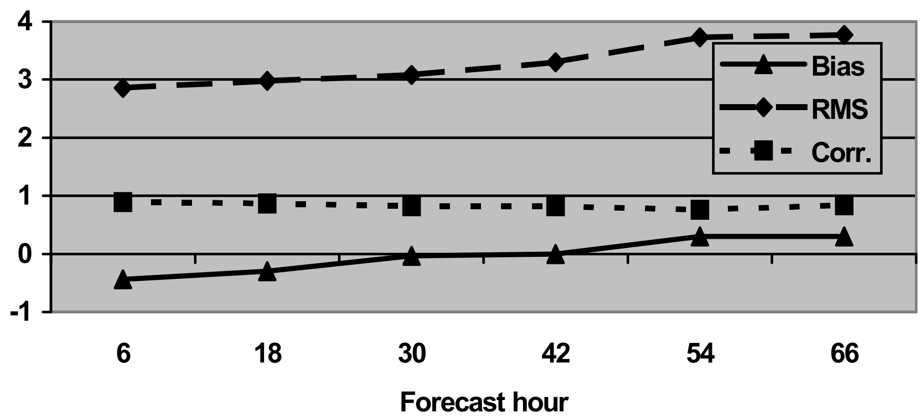


***Figure 4. Relative grid-total values of RMS and bias (FCST-SSM/I) in m s$^{-1}$ are plotted for each forecast hour as dashed and solid lines, and the correlation coefficient between the FCST and SSM/I speed distributions is plotted as the short-dashed line.***

Over the eastern Pacific, the model tends to produce too many strong southerly wind events associated with Pacific cyclones. On the other hand, when a southerly wind event is actually observed the model does a good job with both the position and magnitude of the event. Northerly wind events show similar but less severe tendencies. There is a modest over-prediction of northerly wind events, but when a wind event actually exists the model handles it well through most of the forecast. The northerly wind events exhibited very little phase error.

*Delayed Nest:* A 1.34 wall time speed-up for a 36-hour model forecast (nest 2 delayed 12 hours) was achieved when computations on nest 2 were not begun until 12 hours into the forecast. Two 36-hour COAMPS simulations were performed on a synoptic high pressure system to examine the accuracy of the COAMPS delayed nest algorithm. The delayed nest run was able to reproduce similar results compared to the control run.

## IMPACT/APPLICATIONS

The base-line QPF statistics established through this study can be used to gauge future model improvements. The QPF validation results indicated a possible precipitation deficiency from the COAMPS convective scheme. The composite verification technique can be easily adapted to validate other type of meteorological events.

## TRANSITIONS

New algorithms for the delayed nest has been transitioned to 6.4 programs (PE 0602435N and PE 0603207N) for applications within COAMPS and for subsequent transition to Fleet Numerical Meteorology and Oceanography Center (FNMOC) and Regional Naval Meteorology and Oceanography Centers for operational use.

## RELATED PROJECTS

A related 6.2 project within PE 0602435N is *BE-35-2-44*, Advanced Moist Physics Modeling.

## SUMMARY

We have conducted the 2001 cold season COAMPS QPF validation over the CONUS area. The results were similar to the previous study on the summer month QPF statistics in 1999. Both results showed not enough heavy precipitation is occurring for grid resolutions greater than 27 km. When the grid resolution was increased to 9 km and the precipitation was explicitly resolved using the microphysical scheme only, the model QPF was improved. The simulation with the new explicit scheme had the best QPF scores. Using the composite verification method, the bulk properties of the forecast and the observed high wind climatology can be reliably estimated. The COAMPS Mistral forecast has a very good skill up to 66 hour forecast time.

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